…rtment of Agriculture Agricultural Research Service September 1992

Agricultural Research

New Inventions: Rocky Road to Success

FORUM

A Product Orientation for Agriculture

Creating innovative, higher value products from basic agricultural commodities is not a new idea. In 1862, the founding fathers of the U.S. Department of Agriculture understood the connection, as evidenced by the department's official seal proclaiming "Agriculture is the foundation of manufacture and commerce."

But it's an idea that's been slow to take hold in this country. Too often, we simply sell raw agricultural commodities, missing the opportunity to create a multiplier effect of greater business activity, more jobs, higher earnings, and increased government revenues if we would only add value to those commodities through some sort of processing.

In manufacturing, chemicals, and pharmaceuticals, we're the leader in value-added goods. Automobiles cost about $5 a pound, a jumbo jet is about $350 a pound, a fighter plane is about $2,000 a pound, and a satellite is about $22,000 a pound. All of those start from raw materials that cost pennies a pound.

But when it comes to agriculture, it's a different story. The United States, despite its tremendous force in global agriculture, needs to do a lot more to maintain and strengthen its place in the world market. Many other countries now offer for sale bulk commodities, and we don't appear to be doing a particularly better job. Thus, for example, our share of the global wheat market has dropped from 48 percent to 31 percent in the past few years.

The problem is, when you're dealing with a raw bulk commodity, you don't have much room to maneuver. Brazil produces soybeans, we produce soybeans, and there's no dramatic difference. Also, soybeans are selling for only a few cents a pound. We should be looking at making soybean products that go for several dollars a pound—products such as chemical intermediates and starch-encapsulated biopesticides. But this means processing, adding value to basic commodities.

If you're going to develop a value-added industry, first you must have an extremely productive agriculture, which the United States has. Next, you must have an extremely active entrepreneurial sector, which the United States also has.

What's needed now is more interaction between government and private industry so they might work together toward commercializing new value-added products from basic agricultural commodities. The Federal Technology Transfer Act of 1986 has helped tremendously by allowing the Agricultural Research Service to license marketing rights to its technology to industrial partners. This makes cooperation much more appealing to them. And now we have what we call the CRADA—Cooperative Research and Development Agreement.

Here's how CRADA's work: ARS enters into a partnership with a private company to develop a piece of research. The industrial partner gets an option on the invention—that is, first chance at an exclusive license on the technology. In such a partnership, you have a product champion in industry and a corresponding product champion in ARS—the scientist.

What do these two bring to the agreement? The scientist brings the discovery, along with a tremendous research network not only within the agency, but worldwide. The industry partner brings the capacity to foster development of the research and the scaling-up of the process to commercial levels. [For more on CRADA's, see the Forum in the August 1992 issue of *Agricultural Research.*]

Also, the industry partner has valuable market information not easily obtained that gives us some insights into market demand. You don't get that market know-how just sitting in a lab.

The result: We deliver innovative technology at an early stage of commercialization, and the industrial partner carries it into the marketplace.

Of course, the whole nation must benefit from this partnership, and it does. ARS has in place nearly 250 CRADA's with both large and small U.S. companies. And in 1991, more than 25 exclusive licenses were awarded to industry, generating for several companies new business enterprises based on technology created by ARS scientists.

But how do you know where to begin in developing new products from agricultural commodities? First, satisfy consumer desires. And there's a mounting need to address "green consumerism"—a demand for environmentally benign products. What can we provide in a product that will meet this demand? To name a few: biodegradable plastics, encapsulated (slow release, targeted) chemical products, and natural food ingredients including colorants, flavorants, and other quality enhancers.

Tempting markets exist for biotechnology-based products. For example, the world market for farm chemicals exceeds $20 billion annually, so opportunities exist for suitably engineered biological control products—from pest controls to plant growth regulators.

This doesn't mean we ought to stop our production and postharvest research on the raw bulk commodities. We must maintain our strength there; that's the basis for the value-added market. But a balance of priorities must be struck between research on low-margin commodities and on high-value, marketable, processed products.

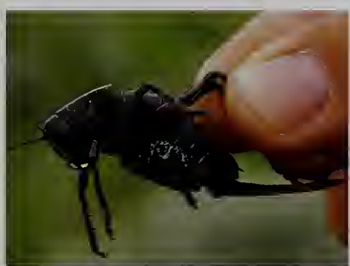
I believe we're turning the situation around. The article on ARS inventions by Sandy Miller Hays that begins on page 4 in this issue shows there's no shortage of innovation among ARS scientists.

And there is an abundance of as yet unexploited innovations from earlier work still awaiting pickup and use by visionary U.S. business concerns.

Ruxton Villet
Deputy Assistant Administrator
for Cooperative Interactions

Agricultural Research

The displayed items represent ARS research to create new uses for agriculture products.
Top row: plastics from vegetable oil, industrial uses for cornstarch.
Second row: cocoa butter substitute, improved cotton processing.
Third row: tallow-based soap, detergents with improved surfactants, new uses for cornstarch.
Fourth row: starch-based rubber products, plastics from vegetable oil, starch-based rubber.
Photo by Keith Weller. (K4796-20)



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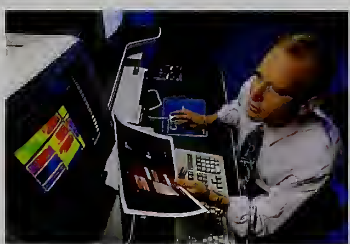

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KEITH WELLER

Inventions Waiting in the Wings

"Build a better mousetrap," the saying goes, "and the world will beat a path to your door."

But it seems that sometimes those clamoring crowds get lost on the way to the inventor's doorstep. The invention is ready, the inventor is eager for interest—and the days tick by uneventfully.

The path to the doorsteps of inventors with the Agricultural Research Service has been smoothed considerably by the Federal Technology Transfer Act of 1986.

This act encourages companies to work with ARS scientists under a formal Cooperative Research and Development Agreement. In return, these cooperating companies get the first chance at exclusive licenses to use the technology that emerges from the joint effort.

The Agricultural Research Service has obtained more than

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1,200 patents to date, and 411 licenses have been granted to companies or universities. But there are plenty of inventions still waiting on the shelves; what follows are a few of the more intriguing "might-have-beens" that still have development potential.

Bouncing Bushels

In the classic silent film "The Gold Rush," a starving Charlie Chaplin makes a hilarious meal of his shoe, right down to the shoelaces. And William M. Doane knows a way the rubber sole might at least have been tastier, if not more nutritious.

Doane, who works in the Plant Polymer Research Unit at the National Center for Agricultural Utilization Research (NCAUR) in Peoria, Illinois, says that starches from plants such as corn can make up as much as 30 percent of rubber products, be they shoe parts, kitchenware, or automobile tires.

Of course, Doane doesn't expect a big demand for edible shoes. But he says switching to starches as rubber reinforcing agents could significantly reduce reliance on a prime ingredient with a petroleum base: carbon black.

"Manufacturers start with a big chunk of material called elastomer, and they add as many as 40 ingredients to make it become the rubber we know," he says. "Up to 30 percent of a tire may be reinforcing agents."

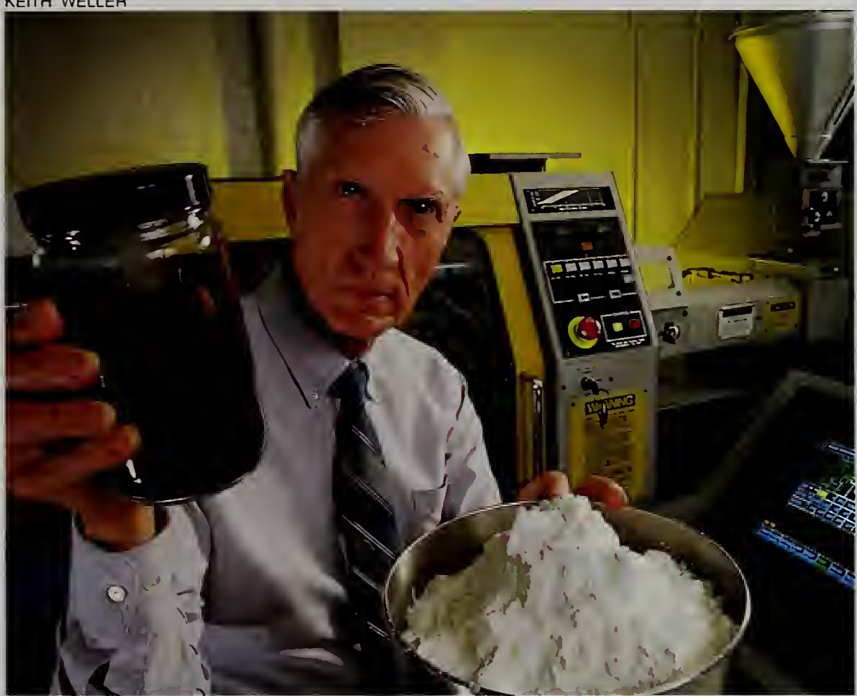
Carbon black is a major player among those reinforcing agents, with a 3-billion-pound annual market that practically begged the attention of ARS researchers, Doane says.

"We started finding ways to make a starch derivative we could put right into the latex," he recalls. "One advantage would be that without the carbon black, you'd have "white" rubber that could be colored any way you wanted."

The Peoria researchers actually hit the development jackpot twice: with reinforced rubber containing up to 30 percent starch and with a powdered rubber process that uses 3 to 5 percent starch and cuts the time it takes to go from raw rubber to molded product by 90 percent.

The type of starch can vary, Doane says, "but we found cornstarch is generally less expensive. As far as performance, though, there's not much difference among starches from corn, wheat, or grain sorghum."

KEITH WELLER



Chemist Bill Doane says that cornstarch can replace carbon black in rubber products, making it easier to manufacture light-colored rubber and conserving a petroleum-based resource. (K4751-1)

Both reinforced and powdered rubber formulations were patented in the late 1960's. "But we couldn't give an exclusive license in those days, so firms weren't interested," Doane says.

"There's certainly still a market. You can get 30 pounds of starch per bushel of corn, so something that uses 3 billion pounds of starch would mean a market for an extra 100 million bushels of corn."

Grow Your Own Plastic

A crop called crambe is growing on some 20,000 acres in the United States this year. But if you want to see what comes from crambe, don't watch your local produce section—check out the plastic goods instead.

Crambe is touted as a domestic source of erucic acid, which now comes into the United States mainly in the form of rapeseed oil from Canada and Europe.

When erucic acid is treated with ammonia, it forms amides, an excellent material for preventing various types of plastic sheets or films from sticking together as they're manufactured and used. Amides constitute a profitable market for erucic acid, but as the United States boosts its crambe production, other outlets will be needed as well.

Enter Nylon 1313, so called because the erucic acid molecule is split and treated to form the nylon's 13-carbon polymer chains.

"Nylons are all very solvent resistant, tough, and strong," notes Kenneth D. Carlson who works in the NCAUR's Oil Chemical Unit and the New Crops Research Unit. "But Nylon 1313 is special because it absorbs the least amount of moisture of any commercial nylon made so far."

This means Nylon 1313 can be molded into items such as automobile

parts, gears, and tubing that must not swell or shrink in humid settings. Nylon 1313 absorbs only about 0.7 percent moisture; by comparison, its cousin, Nylon 11, used in parts for autos and trucks, absorbs about 1.5 percent.

Nylon 1313 stirred some interest, but commercialization was hindered by the expense of the process for splitting the erucic acid molecule. Now new processes developed at North Dakota State University with state and USDA funding may cut that cost in half, Carlson says.

"Nylon 1313 has also been held back by low supplies of erucic acid, which hasn't been available at sufficiently low cost," he adds. "But if crambe production moves along as it is now, that cost could come down."

Cleaning Up Naturally

Detergents may sound like a dirty word to environmentalists, but Warner M. Linfield knows of one detergent that could be good for your clothes, the environment, and the economy: soap.

The problem is, ordinary soap doesn't wash well in water that's cold or hard—loaded with calcium or magnesium. When soap meets hard water, a curdlike substance called lime soap forms—the culprit behind bathtub ring. And there's more bad news: When you use soap to wash laundry in hard water, your clothes come out feeling greasy.

The solution is to add a surfactant—a material in the soap that lowers surface tension so water can penetrate better. At the Eastern Regional Research Center (ERRC) at Philadelphia, Pennsylvania, where Linfield was a research leader until his retirement in 1984, the surfactant of choice came from a natural product: tallow.

"Tallow is mostly beef fat from meat packinghouses and food processing companies," says Linfield. "We wanted to find a way to use it."

Linfield and coworkers blended soap with tallow-based surfactants called lime-soap dispersants. The principle of soap plus surfactants is not a new one, but it has never been used commercially for laundry cleaning.

Linfield's resultant tallow-laced soap is very environmentally friendly. The soaps contain no phosphates; won't harm humans, livestock and domestic animals, or wildlife; and will usually biodegrade within 24 hours. "Bacteria in the sewers and soil eat them up," says Linfield.

While some U.S. toiletry manufacturers use old-fashioned soap with lime-soap dispersants, Linfield says it's not used in the United States as a laundry cleaner. But that's not because it won't do the job.

"We conducted our own tests, and a large soap company also ran tests," he recalls. "We used cloth artificially soiled with fat and lamp black and measured the grayness left after laundering.

"Our soap took out as much as the leading laundry products. The soap company got the same results on laundry bundles. They told us if they'd known about this in the 1950's, they wouldn't have gone to petrochemical-based detergents."

A major reason for the detergent industry's reluctance to change is the expense of scrapping current equipment and switching to soap-making gear.

"That wouldn't be anything small," Linfield admits. "But these soaps would be good for the environment and economical, too."

KEITH WELLER

Chemist Warner Linfield (retired) displays samples of ARS invented tallow-based soap made in the United States and detergents made in Japan and France. (K4756-2)

All-American Chocolate

Tallow could also constitute a good substitute for imported cocoa butter, one of the world's most expensive food fats. At ERRC, scientists in the 1970's actually produced chocolate bars made from edible tallow. [See also "Cocoa Butter from Cottonseed Oil," *Agricultural Research*, June 1992, p. 18.]

KEITH WELLER

A cocoa butter substitute made from edible tallow can replace imported cocoa butter in many products. (K4782-11)

"The thing that's special about cocoa butter is its physical characteristics," notes chemist James W. Hampson, who worked on the project.

"It's a solid at room temperature, but it melts at body temperature. It completely melts in your mouth, and there's no waxy taste. Also, it comes out of a mold easily."

But cocoa butter probably doesn't seem so sweet to budget-watchers at candy companies: The United States last year imported about 205 million pounds of the fat, with a customs value of more than $279 million.

As a substitute, edible tallow is hardly in short supply; U.S. production for the marketing year that began October 1, 1991, is expected to hit 1.35 billion pounds.

The Philadelphia researchers knew the composition of certain fat molecules called triglycerides were similar in tallow and cocoa butter, so they began studying the tallow triglycerides' other qualities, such as melting characteristics.

"There were more similarities than differences," Hampson recalls.

Limiting factors proved to be the relatively complex process used to extract the tallow triglycerides and questions about whether a tallow chocolate bar could be labeled kosher. The scientists' process was ultimately patented and several companies obtained licenses, but Hampson says interest has since waned.

"We were shooting for a cocoa butter equivalent, not just a substitute," he says. "I think we came pretty close."

Putting Fat To Work

Imagine being able to take off fat as though it were a raincoat. It could come true—if the plastic in the raincoat were made from fat.

That's no pipe dream, says microbiologist Rodney J. Bothast. He says all kinds of plastics—even for clothing—can be made from fats, especially vegetable fats such as those found in soybean oil.

"Back in 1978 when we were so concerned about using renewable resources for fuel, we became once again interested in using vegetable oils for diesel fuel," recalls Bothast.

KEITH WELLER

Microbiologist Rodney Bothast adjusts a laboratory fermenter that uses glycerol from vegetable oil. After fermentation and a couple of intermediate steps, the glycerol becomes acrylic acid that can be used to make plastic goods. (K4755-9)

"The backbone of fat is glycerol with three fatty acids attached. When fuel is made, the fatty acids are used in the fuel, and the glycerol is left over."

Researchers at the NCAUR fermented the leftover glycerol using a bacterium called *Klebsiella pneumoniae* to produce a material called 3-HPA (3-hydroxy-propionaldehyde) .

Heating 3-HPA turns it into acrolein. When a single oxygen molecule is added to acrolein, the result is acrylic acid, which can be used to make plastic goods, "everything from artificial fingernails to car bumpers," says Bothast.

Acrylic acid is now made from petroleum, and it takes 3 pounds of petroleum to produce a single pound of acrylic acid.

"In our process, you can use corn, vegetable fat, or any other kind of fermentable material," says Bothast. "We can even use animal fat."

Consumers probably won't see plastics from fats until the alternative fuels industry picks up steam, Bothast says, because that's likely to be the best source of abundant glycerol.

"If a cheap glycerol source exists, this could be done," he says.

One- Step Yarn

Making a simple cotton yarn can be anything but simple. Just ask research physicist Devron Thibodeaux.

"It typically takes five different machines to make spun yarn from a tuft of cotton," says Thibodeaux, a researcher in the Southern Regional Research Center's Fiber Physics and Biochemistry Research Unit at New Orleans, Louisiana. "Each of those machines makes its own product that must be carried to the next machine."

ARS researchers at New Orleans had a better idea: a single machine that can take in the raw cotton at one end and spit out yarn at the other, cutting down on floor space, energy needs, and, best of all, costs.

The machine has three stages of production—fiber preparation, fiber distribution, and yarn formation. Various components of the machine have been patented and are being used by the textile industry, although no one has yet put the overall package to work, says Thibodeaux.

ARS

This experimental machine being fed by technician Craig Folk converts raw cotton into yarn thus potentially replacing as many as five separate machines now used in commercial spinning.

In one economic study, floor space for a conventional open-end spinning system was calculated at about 66,378 square feet, compared with only 15,744 square feet for the tuft-to-yarn system.

The same study estimated manufacturing costs using open-end spinning at about 22 cents per pound of spun yarn, compared with about 18 cents using the tuft-to-yarn system.

"One reason this was not picked up by industry is that back in the 1970's when we did the work, we couldn't grant an exclusive license to a company, so no one in industry wanted to get involved," says Thibodeaux.

"We built one of these machines, and we showed that it will work for a wide range of commercial yarn sizes," he adds. "But for now, it looks like the textile industry is satisfied with the equipment it already has."

Drugs From Nature

You don't have to go all the way to the South American rain forest to find cancer-fighting drugs. The weedy field across the way may serve just as well, if it's loaded with certain members of the sesbania family.

Sesbania drummondii, S. punicea, and *S. vesicaria* all contain a substance called sesbanimide that has demonstrated anti-tumor activity in mice with leukemia, according to ARS chemist Richard G. Powell, who is in NCAUR's Bioactive Constituents Research Unit.

Livestock producers have long been wary of these weeds, commonly known by such names as rattlebrush, rattlebox, coffeebean, bagpod, and bladderpod, because grazing animals as well as chickens and hogs can succumb to the powerful toxins in the seeds.

But when extracts from *S. vesicaria* were sent to the National Cancer Institute in the 1960's for testing as part of a random sampling of various plants, scientists began looking at sesbanias in a whole new light.

In NCI tests, mice that received only 0.01 milligrams of sesbanimide per kilogram of body weight survived leukemia 1.71 times longer than mice that received none of the toxin.

But sesbanimide isn't without problems. For starters, it's hard to come by: 1,000 pounds of sesbania yields only about 2.5 grams of sesbanimide.

Also, "The line between the effective dose and the toxic dose is very fine," he adds. "With drug treatments for cancer, that's always a problem, because the treatments are often toxic to all cells, not just the cancerous ones."

Furthermore, Powell emphasizes, lengthy and expensive clinical tests would be required before these results could be applied to humans.

At least one major pharmaceutical firm has studied sesbanimide and has been stymied by its obstacles. To date, sesbanimide remains a tantalizing puzzle.

"The hope is to find cancer drugs that are specific for certain tumor cells, not just generally toxic," Powell concludes. "Sesbanimide is generally toxic, although it has shown some specificity for leukemic cells in mice."

Horace G. Cutler is another ARS scientist who sees solutions to people's problems in nature. Leader of the Microbial Products Research Unit at Athens, Georgia, Cutler focuses on microorganisms as weapons.

"One of our first compounds was isolated in 1977-78 from old unbleached flour," he recalls. "It was called hydroxyterphenyllin and it turned out to have rather interesting plant growth regulatory effects."

In other studies, Cutler has found a compound from a mold growing on pine logs that's effective against *Aspergillus flavus,* the fungus that produces aflatoxin in peanuts and grain. Also, he's recovered a compound from rotten pecans that fights late blight of potato, the crop disease that prompted the great migrations from Ireland in the 1800's.

"Nature is highly ingenious," he says. "You have to consider all the possibilities. We've discovered a lot of natural compounds with which to safely protect our food supply."—By **Sandy Miller Hays,** ARS.

For information about these ARS inventions, contact M. Ann Whitehead, Patent Coordinator, USDA, ARS, OCI, Room. 403, Bldg. 005, BARC-West, Beltsville, MD 20705. Phone (301) 504-6786, fax number (301) 504-5060. ◆

A stain-removing enzyme from the sea

Shipworms Bring You Another Washday Miracle

The next environmentally friendly detergents for home and industrial use may contain a stain remover made by an unnamed bacterium found in a gland in shipworms.

From among many proteins spewed out by the bacterium, ARS scientists have isolated one, a protease, or enzyme, that digests other proteins such as those in bloodstains or spilled milk.

At a laboratory in the National Center for Agricultural Utilization Research, Peoria, Illinois, the bacterium has been coaxed into producing the enzyme by itself and does it quite well in an aerated fermentation broth containing cellulose and nitrates.

"Nonphosphate detergents that get clothes clean without wrecking the environment may well include the alkaline protease enzyme," says chemist Harold L. Griffin, who works at the center. The protease removes stains and brightens clothes in laundry water made highly alkaline by some components of nonphosphate detergents.

It's as efficient at room temperature as it is at normal wash temperatures of about 120°F. At the higher temperature, the enzyme remains highly active for at least an hour, and "It even thrives in laundry water that includes bleach and other detergent additives," he says.

The enzyme's compatibility with bleaching agents such as sodium perborate and myriad components in detergent formulations contributes to its commercial potential. Three major firms have expressed interest in the enzyme. Griffin and coinventors Richard V. Greene and Michael A. Cotta have applied for a patent.

In laboratory tests, the enzyme worked well in water containing oxidizing and chelating agents as well as with large amounts of salt. With few or no detrimental effects from a broad range of alkaline and acidic environments (pH values between 3.0 and 11.0), the enzyme could become an ingredient in many products. Possibilities Griffin cites include household cleansers, leather dehairing agents, and contact lens cleaning solutions.

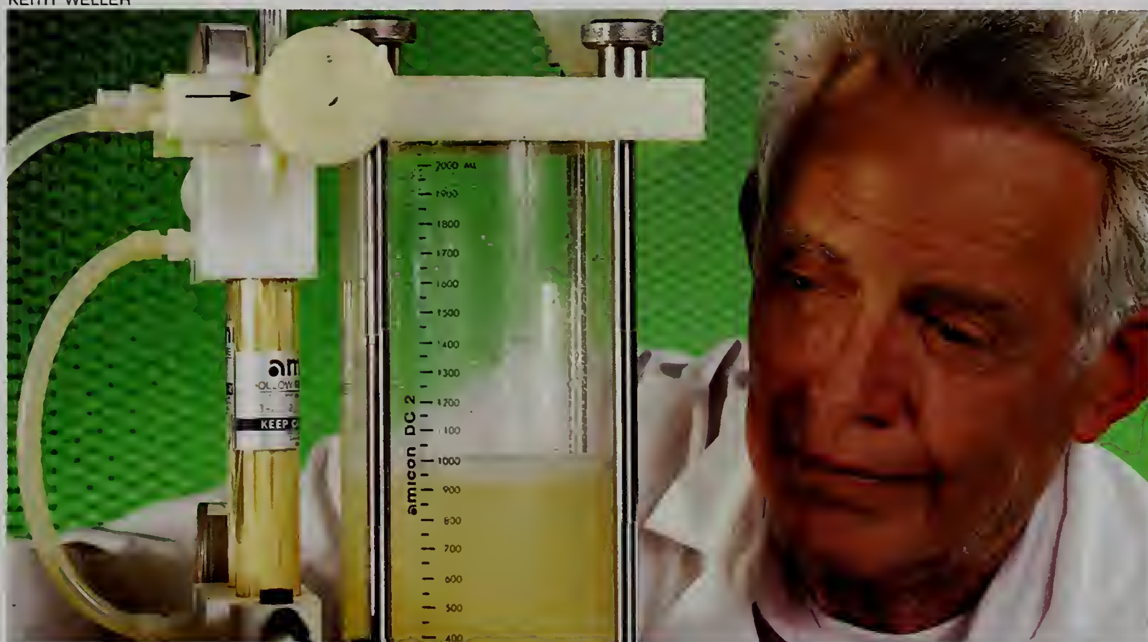
For laundry detergents and presoaks, the scientist envisions the protease taking its place along with several other enzymes including lipases, amylases, and cellulases to enhance removal of different kinds of biological stains.

An enzyme called endoglucanase, also produced by the bacterium, might even be included in specialty detergents. Acting in concert with protease, endoglucanase modifies the surface of cotton fibers to enhance stain removal and give fabrics a stone-washed look.

Laundry detergents containing at least one enzyme make up a $269 million world market today and are projected to reach a value of more than $400 million by 1996.—By **Ben Hardin,** ARS.

Harold L. Griffin, Michael A. Cotta, and Richard V. Greene are at the USDA-ARS National Center for Agricultural Utilization Research, 1815 N. University St., Peoria, IL 61604. Phone (309) 685-4011, fax number (309) 671-7814. ◆

KEITH WELLER



Chemist Harold Griffin extracts an enzyme from a bacterium found in shipworms that is a powerful new stain remover for laundry detergents. (K4678-1)

Termites of the Sea

Marine shipworms, notorious for boring into wooden hulls and pilings, are mollusks in the family *Teredinidae.* The shipworms grow out of their bivalve shells to lengths up to 6 feet.

They have something called the gland of Deshayes, somewhat akin to a salivary gland. It harbors a bacterium that secretes enzymes that enter the worm's esophagus and digest wood fragments. The bacterium parlays nitrogen from seawater into proteinlike nutrients for the shipworm's diet while being nourished by metabolites produced by the shipworm.

ARS scientists in Peoria were first interested in the rare, if not unique, microbe as a means to convert cellulose-laden crop residues into nutritious animal feeds. The idea didn't pan out because the right environment couldn't be achieved to allow the bacteria to fix enough nitrogen quickly.

Natural Microbes May Curb Range Hoppers

Research under way on western rangeland could eventually lead to control of millions of Mormon crickets and grasshoppers in Idaho and Montana.

A one-celled microbe that infects and kills the crickets has been released on rangeland the past two summers as a team of federal and university scientists steps up research on these voracious plant-eaters.

Mormon crickets, which grow to about an inch and a half long when mature, got their name when they attacked the crops of Mormon settlers in Utah in 1848.

MICHAEL THOMPSON

Mormon cricket female. (K4797-1)

Jerome A. Onsager of the Agricultural Research Service says the beneficial microbe is a protozoan, a *Vairimorpha* species that does not harm other insects but can infect up to 90 percent of the Mormon crickets in an area. "We hope this microbe will stop the cricket's occasional population explosions," he says, "and thereby eliminate costly spraying of insecticides needed to protect crops and range plants."

The microbe joins another naturally occurring organism that successfully controls the cricket's menacing cousins—grasshoppers. *Nosema locustae,* also a protozoan, is now commercially available, thanks to previous research efforts by ARS scientists in Montana.

Onsager, who is at ARS' Rangeland Insect Laboratory, Bozeman, Montana, says scientists are building on accomplishments from the grasshopper work.

They have placed a wheat bran bait containing the new protozoan in several small isolated areas of southern Idaho and western Montana where crickets have been a problem historically.

Scientists noted that during the first summer, more than half the insects at some test sites were infected, reducing egg production among infected females by up to 90 percent.

MICHAEL THOMPSON

A barley field near Saint Anthony, Idaho, showing severe damage from Mormon crickets. (K4798-1)

Crickets in a laboratory study were each inoculated with up to 10 million protozoan spores, and some individual insects went on to multiply that number to 10 billion spores. The protozoa survived the winter in or on cricket eggs and started new infections the following year.

"*Vairimorpha* occurs naturally in Colorado and Utah," says Montana State University entomologist John Henry. "It could be the most promising long-term weapon against Mormon crickets." Henry leads the tests in collaboration with ARS and other cooperators. Now an adjunct professor at the university in Bozeman, he recently retired from the ARS Rangeland Insect Laboratory.

The tests are part of a cooperative grasshopper management project that involves, in addition to ARS, the U.S. Department of the Interior's Bureau of Land Management, USDA's Animal and Plant Health Inspection Service, county extension agents, Ricks College in Rexburg, Idaho, and area ranchers.

"We want to gather enough data to assess the feasibility of boosting the natural levels of the protozoan," says Henry. "We don't want to wipe out Mormon crickets—we only want to prevent their periodic population explosions that overwhelm natural controls. Mormon crickets can actually be beneficial because they eat some undesirable plants and scrounge on animal wastes."

"If we can figure out effective ways to spread this natural control among the crickets, we could avoid spraying insecticides," he says. Chemicals kill the crickets quickly but can also harm good insects such as bees.

Vairimorpha acts slowly, taking up to 12 days to multiply inside young crickets

that it kills by consuming their fat. Older crickets take longer to die or may even survive, but infected females lay fewer eggs. They can pass *Vairimorpha* on to their offspring, and all growth stages are very susceptible to the infection. It spreads by spores passed in feces, as well as by cannibalism and venereal means.

Says Onsager, "We are also looking at viruses that naturally infect grasshoppers. One of these, the *Melanoplus* entomopoxvirus, looks promising." In 2 years of field studies, ARS entomologists Douglas A. Streett and Stephen A. Woods found that it infected more than 25 percent of some grasshopper populations.

They report that when the weather is conducive and under crowded conditions, grasshoppers often partially consume the corpses of their dead brethren. Such a high scavenging rate increases the spread of the virus.

"Right now, *Nosema*—which costs about $2.50 per acre for control—is much cheaper to produce than the virus. This is primarily because the virus tends to kill its hosts at lower levels of infection than the protozoan. Therefore, we need to raise more grasshoppers in the laboratory to produce an acre's dosage of the virus," says Streett.

Just one *Nosema*-infected grasshopper produces enough protozoa to treat 9 acres, whereas 30 to 40 grasshoppers may be needed to produce enough virus to treat just 1 acre.

But as with protozoa, the key to most efficient control will be learning how to properly apply the control agent. If workers apply too much, the insects die before they can spread infection around the range. If they don't apply enough, the insect populations soar out of control.—By **Dennis Senft**, ARS.

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MICHAEL THOMPSON

Biotechnician Jerry Mussgnug collects Mormon crickets for laboratory study near Saint Anthony, Idaho. (K4797-2)

Minimizing Catfish Flavor Problems

When Huey Priest and Ray Roberts brought samples of their harvest-ready catfish to a Wisner, Louisiana, processing plant, they received grim news.

Flavor testers at the processing plant informed the two Wisner catfish farmers that their fish were off-flavor and not acceptable for processing.

"I'd say off-flavor is 50 percent of our production problems," says Priest, who is farming thirteen 10-acre catfish ponds. "I think we've pretty much licked disease, but we still have to deal with off-flavor."

Off-flavor in catfish is largely the result of poor water quality in ponds. In many cases, algae are the prime culprits because they emit natural chemicals, such as muddy-smelling geosmin.

Catfish tend to absorb these natural chemicals that are released into pond water when algae get sick or die.

The resulting problem costs Priest, Roberts, and other catfish farmers about $12 million a year in lost production. If samples of marketable catfish are turned down at the processing plant, catfish farmers have to wait until the off-flavor compounds naturally purge from their fish.

The two farmers have also found that the chances of getting off-flavor catfish are higher during warmer months.

"This time of the year, you don't have a whole lot of things you can do," Priest said during an interview at his farm last May in 90-degree-plus temperatures. "The only thing actually recommended is moving the fish from one pond to another.

"But I've never done that in the summertime because it stresses the fish," he continued. "When you stress your fish, you're going to get disease."

The more than 1,900 catfish farmers nationwide have very few means available to combat off-flavor and ensure that their market-size catfish consistently meet processors' stringent flavor quality standards.

SCOTT BAUER

Viewed from the sky, an array of catfish ponds in Louisiana resembles an abstract painting. The color differences between ponds can be correlated to the number and type of algae present within the ponds. (K4724-7)

However, Agricultural Research Service scientists are working on better ways for farmers to operate their ponds to reduce the incidence of off-flavors.

"Remote-sensing imagery provides a reliable estimate of algae activity in catfish ponds that can help farmers better manage their ponds," says Peter B. Johnsen, research leader of the project at ARS' Southern Regional Research Center in New Orleans. "The rapid growth and death of blue-green algae populations cause sudden deteriorations of water quality."

Johnsen and fellow researcher David F. Millie, a microbiologist at the center's Food Flavor Quality Research Unit, are working on ways to correlate images from aircraft-carried remote-sensing equipment with various stages of algae growth and health.

The researchers began their studies in 1990 by obtaining readings from a sensor mounted on a NASA Learjet. The plane flew over Mississippi catfish ponds to obtain information on the algae pigments in the water.

The sensor recorded wave lengths that were ultimately translated into specific pigments. The color and amount of pigments indicate the type of algae present in the pond, their numbers, and health status, Johnsen says.

While remote sensing from satellites can detect the presence of algae, Millie says the images are recorded from too far away to provide a sufficiently clear picture to ascertain the health of individual algal types.

Some catfish farmers, like Priest and Roberts, currently have weekly water samples analyzed for off-flavor. But

he says. "The advantage to this system would be that it scans a lot of ponds and does it relatively quickly."

Scientists have measured several types of healthy algae, each of which shows a characteristic pigment "fingerprint." Variations in the pigments indicate the condition of the algae.

"It's rather like what happens to trees when they change colors in the fall," Millie says. "Different species turn different colors, revealing various pigments at different times.

"While the algae may have different colors, we can't see subtle differences with the naked eye," says Millie. "But the sensor looks at one specific band at a time and can register those differences.

"In addition to all the pigments that indicate specific algal types, the airborne sensor might also be able to detect deviation from a healthy fingerprint signature. So, if a particular alga were to appear more yellow, for example, it might indicate stress and the likelihood of releasing off-flavor compounds."

Johnsen also envisions another use for the remote-sensing system—monitoring oxygen levels in pond water.

"Algae produce oxygen during the day by photosynthesis but consume it at night," he says. "Since the system may be able to show fluctuations in oxygen amounts, it could help farmers manage the oxygen in their fish ponds."

If oxygen levels are low, information obtained from the sensor will be able to tell when, how often, and at what locations to aerate the ponds. Oxygen management is a key to fish production efficiency, Johnsen says, because low levels result in stress, low growth rates, and mortality.—By **Bruce Kinzel,** ARS.

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Priest says it normally takes 3 to 5 days to obtain results from these analyses.

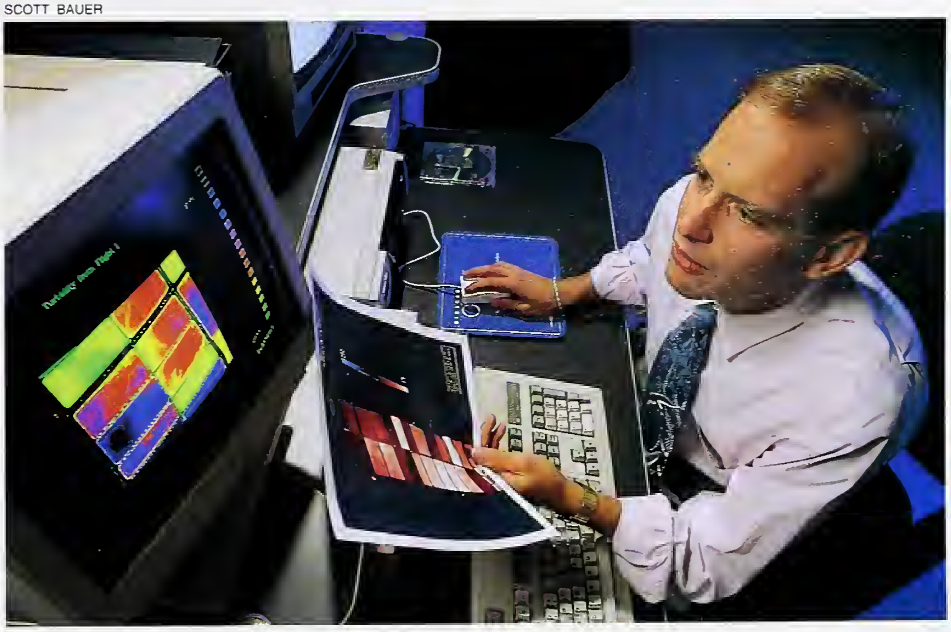
And Johnsen says the condition of algae in ponds can change hourly—depending on such factors as temperature, light levels, and nutrients.

As the research progresses, Millie envisions the use of sensors on small airplanes to collect information that could be read on a personal computer.

"Pilots could go up, fly over several farmers' ponds, return, and download the data onto a disk for use in a personal computer," Millie says. "Once mathematical calculations were made, the data could be communicated to farmers so they would know which ponds need to be treated and how often.

"We're talking about just a matter of hours, so the farmer might know that very evening what treatment to start."

SCOTT BAUER



Digitized images on the computer monitor represent catfish ponds as seen from the air. By using the quantitative color key (on right of screen), microbiologist David Millie can depict the algae growing within the various ponds. (K4779-6)

Vitamin E Is for Exercise

We've all done it: jumped into an activity that demands more of some muscles than they're used to giving.

For the next few days, those muscles let us know they have suffered mechanical damage—the result of individual cells tearing apart as they lengthen under force. But a second kind of damage, caused by free oxygen attacking cell membranes, may also contribute to the soreness.

"Animal and human studies have shown that exercise induces the production of oxygen free radicals," says Mohsen Meydani, a nutritionist at ARS' Human Nutrition Research Center on Aging at Tufts in Boston.

He and colleagues conducted a study to see if vitamin E, an antioxidant, could reduce muscle damage caused by these radicals and by other responses to heavy exercise.

Meydani says findings with two age groups of sedentary men who pushed their leg muscles well beyond their usual efforts indicate that "vitamin E provides protection against exercise-induced oxidative damage—in both young and older people."

During exercise, he explains, the blood delivers extra oxygen to the muscles in the form of O_2. But some of that oxygen escapes the controlled metabolic process as single oxygen ions, known as free radicals.

These negatively charged ions behave like pickpockets, stealing positively charged hydrogen ions from the fatty acids in cell membranes. This damages the membranes—the gatekeepers of muscle cells—breaching their integrity. By donating the hydrogen ions these free radicals are looking for, vitamin E protects cell membranes, he says.

In the study, 21 normally sedentary men each spent 45 minutes running downhill on a treadmill in the center's physiology laboratory. Nine of the volunteers were in their 20's and 12 others were 55 to 74 years old. The researchers wanted to compare vitamin E's effects in young and older men because body levels of antioxidant enzymes reportedly diminish with age.

Half of each age group began taking 800 I.U.'s (International Units) of the vitamin daily, 7 weeks before the day of exercise, and resumed taking the supplement a few days afterward. The other half got placebos.

Also, muscle biopsies, which were taken only from the younger group's lower legs, showed a similar trend in oxidative damage, Meydani says. An intermediate byproduct of fatty acid oxidation tended to be lower in the supplemented men.

Older people may benefit even more than the young from stocking up on vitamin E before diving into a workout their muscles aren't used to. Although oxidation was reduced in both groups, he says, the data suggest that "the older men were better protected."

SCOTT BAUER

Nutritionist Mohsen Meydani analyzes plasma samples from volunteers that have just completed vigorous exercise. Volunteers were supplemented with vitamin E for 48 days. (K4614-8)

Meydani says the team didn't assess muscle soreness, which is a subjective measurement. But the supplemented men in both age groups had a significantly smaller increase in urine byproducts that indicate fatty acid oxidation by the 12th day after exercise.

Earlier studies at the Boston center showed that exercise can cause delayed damage and repair of muscle fibers that takes up to 2 weeks, which could explain the 12-day lag in this study.

Meanwhile, nutritionist Simin N. Meydani and colleagues looked at the vitamin's effects on immune response. Earlier research at the center suggested that prolonged or damaging exercise triggers the immune system to respond much the same as it does to infection. Using oxygen free radicals and enzymes, it launches a full-fledged attack

against the body's own damaged muscle tissue that is coordinated by chemical messengers known as cytokines.

The researchers think this inflammatory response helps to break down and clear away damaged muscle cells so that new tissue can be put in its place. But it may get out of control and break down healthy muscle tissue as well.

There's some evidence that vitamin E reduces the inflammatory response that occurs with arthritis, says Simin Meydani. So the researchers wanted to see if it had any effect on the inflammatory response to exercise, especially in the older men.

She says vitamin E affected the amount of cytokines secreted by the men's white blood cells, but it didn't discriminate according to age. Both groups secreted less of two of the three cytokines tested if they got vitamin E supplements. Those who got placebos had a 154-percent rise in interleukin 1 production a day after exercise, compared with no significant rise for the supplemented men. And interleukin 6 secretion was higher in the placebo group both before and after exercise. The two cytokines work together in the inflammatory process, says Meydani.

"It appears that vitamin E is controlling the magnitude of the inflammatory response," she notes. "Supplemented subjects may have less muscle damage as a result."—By **Judy McBride,** ARS.

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Breeding Salt-Tolerant Tomatoes

A wild Galapagos Islands tomato that does well in salty soil has lent some badly needed genes to tomato varieties in this country. Agricultural Research Service scientists used this wild species to increase the salt tolerance of commercial tomatoes by about 25 percent.

"We've learned that we can use traditional breeding techniques to develop crops that tolerate saltier irrigation waters," says ARS plant geneticist Michael C. Shannon.

Shannon achieved improved salt tolerance after five generations of crossing the commercial tomato species *Lycopersicon esculentum* Mill. with the wild species *L. cheesmanii.*

He says the commercial types have a natural mechanism to exclude some salt from the water that they use. The wild types take salt in with the water but concentrate it in older leaves.

Field trials of some of the improved tomato lines will begin next year. But—as with most crossbreeding—some bad traits have followed the good. For example, the improved salt-tolerant plants produced much smaller fruit, although overall yield was the same. Shannon says that such salt-tolerant tomatoes might find a niche in the processed-tomato markets.

In other crops that lack a high degree of cross fertility, genetic engineering techniques will be needed to identify and then move specific genes from one species to another. But because salt tolerance is a complex characteristic involving many genes, breeders have not yet found reliable genetic engineering techniques to increase its expression.

"Salt tolerance is now important in many farming areas where irrigation water is brackish," says Shannon, "and it will become even more important if farmers reuse their water. Irrigation water gets saltier with each use because most plants prevent uptake of dissolved salts. This leads to ever-increasing concentrations of such salts as sodium and chloride in the water."

Reusing irrigation water is one strategy researchers are looking at to conserve finite water resources. Most major waterways and aquifers have already been developed and are providing drinking water for rapidly expanding urban areas and supplying irrigation water for agricultural production.

"It's imperative that we learn how to make more efficient use of existing water supplies," says Shannon who is in the Plant Sciences Research Unit at the U.S. Salinity Laboratory in Riverside, California.

The saltiest water Shannon used in his studies was about 13,000 parts per million, or about 8 to 10 times saltier than irrigation water taken from the Colorado River in southern California.—By **Dennis Senft,** ARS.

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Let's Hear It for Lesquerella!

Kneeling in a 20-acre pilot production field in Arizona, Anson E. Thompson checks lesquerella for seed set. Oil from the seeds can be used to make cosmetics and a variety of other products. (K4692-2) (Facing page K4690-14) Photos by Jack Dykinga.

Lesquerella has the potential to become the nation's newest commercial crop, with U.S. farmers growing this oil-bearing plant as early as 1997.

It's not impossible for such a shift to be so swiftly made. American farmers have proven to be very adaptable through the years. As economic conditions have changed, many have sought new or alternative crops or methods.

For example, earlier in this century as tractors became available, farmers sold their draft animals. This made land that previously grew oats and hay for horses and mules available for other uses, so many farmers opted for soybeans. From practically no production in 1900, soybeans now rank second only to corn with U.S. farmers, who produce half of the world's soybean supply.

"Key to a viable, flexible U.S. agricultural industry is support for ongoing research programs for potential new crops," says Anson E. Thompson, plant geneticist with the Agricultural Research Service. That way farmers won't be left in the lurch as markets for agricultural goods fluctuate or as foreign competition intensifies in various product areas."

Says David A. Dierig, also a geneticist at ARS' U.S. Water Conservation Laboratory, Phoenix, Arizona, "Just 7 years ago, lesquerella was growing wild in Texas and parts of Arizona, New Mexico, Utah, Colorado, and Oklahoma. Since then, we have evaluated 23 of 70 known species and selected and bred plants that can produce more than 1,800 pounds of seed per acre—up from about 1,000 pounds."

The most promising species is *Lesquerella fendleri,* a native of southeast Arizona, New Mexico, Texas, and Oklahoma.

Private industry is interested in lesquerella. Two firms joined with ARS and the University of Arizona to grow 26 acres during the 1990-91 growing season and more than 70 acres in 1991-92. Already, a cosmetics firm has expressed interest in purchasing commercial quantities of oil in 1993. And a commercial oilseed processor has cooperated with ARS researchers to develop oil-extracting techniques.

The oils can be used in resins, waxes, nylons, plastics, high-performance lubricants, corrosion inhibitors, and coatings, as well as in cosmetics such as lipstick and hand soap.

The oils can be used in resins, waxes, nylons, plastics, and lubricants, as well as in cosmetics such as lipstick and hand soap.

"We don't need to develop special seeding or harvesting equipment for growing lesquerella. Commercially available alfalfa seeders and grain combines—with minor adjustments—work fine," says ARS agricultural engineer Douglas J. Hunsaker. Processing equipment used for other oilseed crops also works for lesquerella.

After the oil has been pressed out, the residual meal contains 30 to 35 percent protein with an amino acid balance that's suitable for animal nutrition. It could be used as a protein supplement for livestock rations, primarily for beef cattle. Cattle feeding trials are currently in progress at the University of Arizona, and chicken and rat feeding experiments are under way at Kansas State University.

Oil from lesquerella contains hydroxy fatty acids—special fatty acids that have a hydroxyl group (an oxygen and hydrogen atom) attached to the carbon chain. Castor oil and its derivatives are now the only commercial source of these industrial fatty acids. Two castor oil derivatives, ricinoleic and sebacic acids, are listed as strategic and critical materials by the U.S. Department of Defense. As such, they are important to the day-to-day operations of the nation.

"All castor oil used in this country is currently imported—some 30,000 to 64,000 metric tons annually," says ARS chemist Francis S. Nakayama. It is one of the oldest industrial products produced from an agricultural crop. Ancient Egyptians used castor oil in lamps and for skin and hair treatment. Since then, many modern uses have evolved from the oil and its derivatives.

Lesquerella is seen as a potential new crop that is complementary to castor in products from hydroxy acids.

But slight, important differences in the chemical structure and composition of lesquerella oil could extend its use to new industrial applications. Of special interest are two hydroxy acids—densipolic and auricolic—with unique chemical structures that suggest many new uses.

In the late 1950's, ARS researchers at the National Center for Agricultural Utilization Research (NCAUR) in Peoria, Illinois, began a 20-year search for promising new crops that led to the evaluation of about 8,000 plant species. They analyzed some 25 lesquerella species for oil and hydroxy fatty acid content and discovered ranges

from 11 to 39 percent and 50 to 75 percent, respectively.

ARS chemists in NCAUR's New Crops Group have explored several ways to commercially remove the oil from lesquerella seed and to refine the extracted oil. Methods have been devised to concentrate the hydroxy fatty acids to the levels found in castor oil. These methods use both state-of-the art industrial equipment and enzyme technology.

The group is making greases and unique esters from lesquerella fatty acids for use as possible industrial lubricants. And value-added products are being developed from the meal portion to enhance economic return from the crop. This NCAUR group has also sponsored the animal feeding studies under way at the University of Arizona (with USDA's Cooperative State Research Service) and at Kansas State University.

It wasn't until the mid-1980's that ARS researchers in Phoenix sought to improve the plant through extensive breeding programs, as well as to develop cultural and management practices for growers. This research has been supported by ARS and championed by CSRS' Office of Agricultural Materials, Washington, D.C.

A task force composed of employees from ARS, CSRS, and USDA's Economic Research Service, along with personnel from the University of Missouri, recently completed a study of lesquerella's potential as an industrial oilseed crop. Published in October 1991, their report found no insurmountable barriers to its commercialization. The group evaluated the technical, economic, and institutional aspects of crop production, product consumption, and marketing.

Research on lesquerella at Phoenix during the past 6 years shows that:

- Planting can be done with commercially available alfalfa drills seeding at a rate of 6 to 8 pounds per acre.
- While lesquerella is considered a winter crop, it may possibly be grown as an early spring crop in some climate zones.
- Although native stands grow in arid conditions, commercial production in Arizona will need irrigation. Good yields are possible from 25 inches of water applied during the October-May growing season. That's about the same as the water requirements of small grains raised as winter crops in Arizona but a good bit less than the 42 inches needed for cotton, a summer crop.
- Fertilizer requirements are modest. Lesquerella yields can probably be increased by applying minimal quantities of nitrogen during flowering and seed set. Research on nutrient requirements is in progress in cooperation with the University of Arizona.
- Weed control can be a problem, especially before flowering and seed set, since no herbicides are cleared for use on lesquerella. Researchers in Texas and Arizona are now looking for environmentally compatible and economically feasible methods of weed control.

JACK DYKINGA

Geneticist Anson E. Thompson holds a vial of lesquerella oil processed and refined at the National Center for Agricultural Utilization Research in Peoria. (K4690-10)

- Insects and diseases do not appear to plague lesquerella. However, researchers caution that—as with most crops—large-scale production usually generates insect and disease problems.
- Harvesting is accomplished with standard combines equipped with sieve screens to collect the small seeds.

Says Thompson, "Our biggest challenge now is finding ways to increase seed size (1 million seeds weigh less than 20 ounces) and to increase the number of seeds per plant. This might be accomplished by our breeding program, or we might discover a better way to use honey bees or other pollinating insects to move more pollen from male to female flower parts—the limiting factor in seed set."

Entomologist Eric H. Erickson and staff at the ARS Carl Hayden Bee Research Laboratory, Tucson, Arizona, are cooperating with the Phoenix researchers on a 20-acre field near Maricopa, Arizona, in determining lesquerella's pollination requirements.

And scientists are beginning to collect new germplasm from other areas of the country, including species native to Alabama, Tennessee, Oklahoma, Texas, Colorado, and the Pacific Northwest. Perhaps some of these species will provide valuable genetic material or even new chemical products for industry and export.—By **Dennis Senft,** ARS.

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When These Chips Are Down

Rice Borers Just Can't Get It Together

SCOTT BAUER

When treated with a synthetic copy of the female's sex attractant, rubber and plastic chips and pellets such as these so confuse male Mexican rice borers that they're often unable to find a mate. (K4760-11)

It may seem to the Mexican rice borer that love is on the line, but scented rubber and plastic chips spread in south Texas sugarcane fields could cause this costly pest to get mostly wrong numbers.

The chips, each weighing 20 to 40 milligrams and measuring from 3 to 6 millimeters square, are treated with an artificial copy of the female rice borer's own sex attractant, or pheromone.

The rice borer pheromone was chemically identified in 1983 by ARS chemists Ted N. Shaver and Harold E. Brown. Brown has since retired from ARS and works as a consultant to the sugar industry.

Shaver and Brown conceived the idea of incorporating the chemical into plastic and rubber chips that could be used to confuse the sex-hungry male rice borer in his search for a mate, thus reducing numbers of offspring.

"We tried the pheromone on several types of carriers, but rubber and polyvinylchloride chips looked the most promising," recalls Shaver, who works in the ARS Crop Insect Pests Management Research Unit at College Station, Texas.

"After the chips had been in the fields about 100 days, we saw only a fraction of the usual amount of damage from rice borers. On our control plots where we hadn't used the treatment, 18 to 20 percent of plant stalk sections had damage. But on the treated plots, there was only 3 to 4 percent damage."

Those differences add up to many dollars for the farmers who grow south Texas' 35,000 to 40,000 acres of sugarcane.

Shaver said area sugar producers have estimated annual losses to the pest to be more than $4 million. For each percent of damage, as much as a pound of sugar per ton of harvested sugarcane is lost. Sugarcane typically yields 30 to 40 tons per acre.

The rice borer, *Eureuma loftini,* invaded Texas' lower Rio Grande Valley from Mexico in the early 1980's, and has surpassed the sugarcane borer as the most devastating pest of cultivated sugarcane in that area. The rice borer also has a taste for cereal crops and grasses.

"Nearly every sugarcane field in the area has some rice borers," says Shaver. "When we took samples in fields in 1990, we saw damage levels from 5 to 60 percent."

Insecticides have been the primary weapons against the borer. But control has been difficult because the pest's eggs are tucked between the plant's leaf sheath and stalk, where both eggs and larvae are protected from chemical sprays.

And biological control has been difficult because the rice borer often seals up its entry holes into the plant, preventing or reducing contact with control agents.

Evaluating the extent of the rice borer's presence in sugarcane fields has been time-consuming and expensive, involving the use of sweep nets, field inspections, and dissection of sugarcane stalks to check for larvae.

But recently, Shaver and Brown have used rubber plugs impregnated with the pheromone to lure male borers into moth traps for counts of the pest population. Tests have shown the lures are still effective after 140 days in the field.

This innovative sampling system is currently being used by researchers in Texas and Louisiana to monitor the spread of the pest into other sugarcane and rice production areas.

Shaver and his colleagues began additional field tests this summer at Weslaco, Texas, to determine precisely how the pheromone-laden chips affect the pests. The work is being done in cooperation with the ARS Subtropical Agricultural Research Laboratory at Weslaco and the Rio Grande Valley Sugar Growers.

Peter D. Lingren, research leader for the College Station unit, says ARS has entered into a cooperative research and development agreement with Consep Membranes of Bend, Oregon, to obtain data necessary to register the product for commercial use and to develop a commercial version of the chips. Rio Grande Valley Sugar Growers is also cooperating in this effort.—By **Sandy Miller Hays,** ARS.

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Getting the Jump on Grass Fires

A warm breeze wafts the pungent smell of sagebrush across a desert range. Huge, high thunderheads roll across the sky, casting shadows over land covered with dry, strawlike cheatgrass. It's a picture-perfect setting for a natural disaster—a dry lightning storm.

A phenomenon common to arid, western states, dry lightning is accompanied by a light sprinkling of rain—or no rain at all—rather than a drenching rainstorm. These peculiar storms spark wildfires in desert rangelands, particularly in Nevada, Idaho, Oregon, and northeastern California.

True, people cause most wildfires. [See chart on page 22.] A carelessly flung cigarette butt or hot automobile exhaust will quickly ignite dry grasses near a highway. But lightning can set many fires simultaneously over large landscapes, increasing the chances for a serious wildfire.

"Wildfires can destroy thousands of acres within a matter of hours," says James A. Young, a range scientist at the ARS Conservation Biology of Rangelands Unit in Reno, Nevada. In 1985, wildfires near Winnemucca, Nevada, charred more than 600,000 acres. Firefighters blamed it on a dry lightning storm, noting that over 50 different strikes within a few hours contributed to the blaze.

These wildfires burn valuable forage grasses that feed cattle and sheep, as well as mule deer and pronghorn antelope. Fires also destroy both shelter and food for wildlife such as kangaroo rats, jackrabbits, and nesting birds—sage grouse, chukars, and sparrows.

To help prevent range fires, ARS scientists are studying new ways to better establish both native and introduced grasses. And they are looking at how fires alter rangeland soils and how those changes may affect plants.

One grass that scientists would like to replace is cheatgrass, an alien weed that flourishes on most western rangelands. "It's not that cheatgrass isn't a good forage," says Young. "In fact, it's fairly nutritious until it matures—typically around mid-July. Then it becomes a dry, fine-textured straw with prickly seedheads that can hurt cattle's mouths. And it's highly flammable."

Other grasses stay green throughout the summer, when cattle graze the range. However, these native perennial species have a hard time competing with cheatgrass, an annual that reseeds itself each spring and sprouts quickly.

"One way to get around that problem," says Stuart P. Hardegree, "is to coax these perennial grasses to sprout more quickly. This may give them a critical head start so they can outgrow cheatgrass."

Hardegree, a plant physiologist at the ARS Northwest Watershed Research Center in Boise, Idaho, is perfecting a way to do just that—a technique called seed matric priming.

"Matric," a term from soil physics, refers to the amount of water available in a matrix. Soil and sponges are good examples of matrixes, which are actually conglomerates of porous material.

The method primes seeds to sprout by plumping them full of moisture without submersing them, so that the seeds actually stay dry on the surface. Matric priming is an improvement over another

JAMES YOUNG

Wildfires burn millions of acres of grassland in the intermountain west. Loss of native shrubs and subsequent cheatgrass invasions decrease plant and animal diversity and fuel later fires.

sprouting enhancement technique known as osmotic priming, in which seeds are soaked in a solution of polyethylene glycol (PEG), a clear, syrupy liquid. The antifreeze used in cars contains a form of the same chemical.

"The main problem is that PEG is a goopy mess, so you have to wash the seeds before they're planted," says Hardegree.

Matric priming, or matric conditioning, as it is also called, avoids that problem. "The seeds never touch the PEG, because they're separated by a thin membrane made of cellulose," he says.

In the laboratory, a pill-bottle-sized germination priming vial holds the solution. Inside is a smaller vial, holding seeds sitting on the membrane.

The membrane's pores keep out the PEG but allow water to seep in, which the seeds in turn soak up. The key is creating the perfect mixture with just enough water for the seeds to begin to metabolize, but not so much that they extend a root, explains Hardegree.

He then compares the germination time of primed versus unprimed seeds, at both 10°C and 25°C (50°F and 77°F). "We find we can cut germination time almost in half with three different grass species," says Hardegree.

At 10°C, thickspike wheatgrass, sheep fescue, and bluebunch wheatgrass normally germinate in 7 to 9 days, but when primed they germinate in 4—about the same as for cheatgrass.

According to Hardegree, the research may benefit a variety of user groups. "Native plant biodiversity is being emphasized more and more these days," says Hardegree. "Instead of revegetating rangelands with a single species, there's a growing trend to create richly diverse areas that include a variety of appropriate species."

With this in mind, the U.S. Department of the Interior's Bureau of Land Management has established an Intermountain Greenstripping and Rehabilitation Research Project.

Greenstripping means planting strips of green vegetation to act as fuel breaks to slow or stop wildfire spread, according to Mike Pellant, a greenstripping specialist with the BLM in Boise.

It's the rancher's version of fuel breaks that homeowners use in fire-prone settings, such as southern California's notoriously flammable canyons of chaparral. There, homeowners are advised to landscape with low-growing, slow-burning greenery.

In Idaho, most greenstrips are about 300 feet wide and have been seeded along highways and railways. Researchers first plow under existing cheatgrass and use special drills to plant the seeds.

So far, the practice has worked well where the seeds took hold. "Two fires that reached greenstripped areas didn't burn through," says Pellant. For example, a greenstrip south of Grasmere, Idaho, helped stop a wildfire in 1988.

But not every planting is a success, notes Pellant. The 6-year drought in the West caused seeding failures in several instances.

Currently, the challenge is to promote better establishments and earlier sprouting, which Hardegree hopes to achieve over the next few years. Seeds with shorter germination times, he says, can take better advantage of favorable conditions—like soil moisture—that may be available only for a short time, as during a drought.

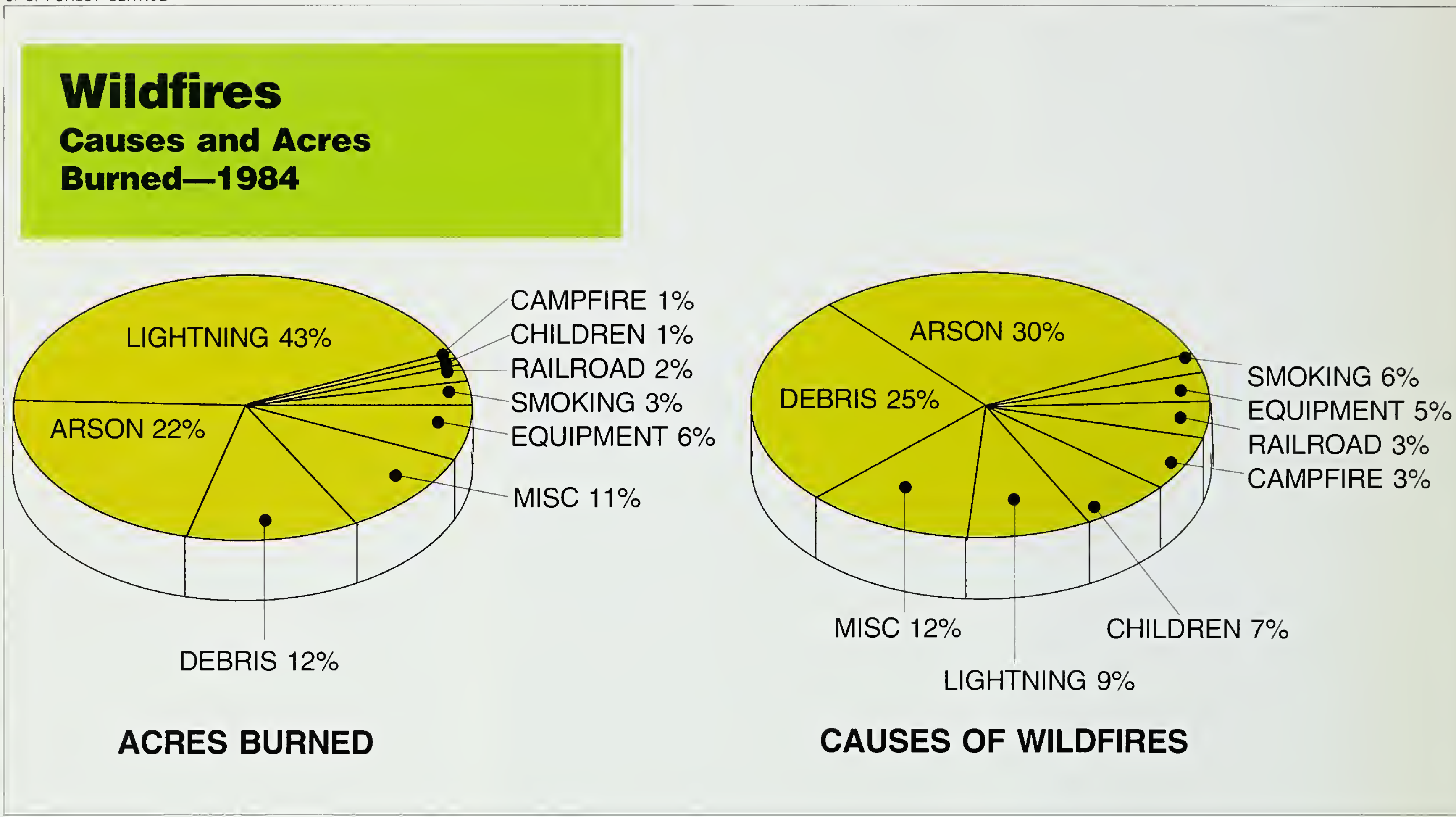
He plans to field test his primed seeds next spring on BLM land near Boise. The following year, he'll gear up for large-scale applications of the priming technique. "Once we determine the optimal amount of water needed to prime a particular batch and type of seed, then we can add just the right amount. And, when the conditions are right, we'll test to see how well the primed seeds do in reseeding a burned-over area."

When flames roar across a range, the soil reaches temperatures above 300°C (572°F). "After soil gets that hot, the growing environment is dramatically altered," says Robert R. Blank, a soil scientist who works with Young.

For one, burned soils are extremely hydrophobic, or very slow to absorb water. That's due to waxlike hydrocarbons—formed by burning plant materials—that coat soil particles. "A drop of water will sit like a bead on top of burned soil for 2 hours," says Blank. Normally, water soaks into most soils almost immediately.

Another difference shown in preliminary studies was the presence of acetic acid and formic acid in burned soils.

U. S. FOREST SERVICE



(Both are quite common chemicals: Vinegar is weak acetic acid, and ants contain formic acid.) "It's possible that these compounds—or others we haven't yet detected—could influence seed germination," he says.

One advantage though: The heat of burning splits apart a potassium-containing mineral called biotite. "The splitting increases the mineral's surface area," explains Blank. "That makes it easier for growing plants to absorb this essential nutrient."

More extensive studies after the next fire are planned for Nevada's Great Basin desert. Blank and colleagues will compare germination times of up to 20 different species of grasses, shrubs, and other plants, seeded in both burned and nonburned areas.—By **Julie Corliss,** ARS.

James A. Young and Robert R. Blank are with the USDA-ARS Conservation Biology of Rangelands Research Unit, 920 Valley Rd., Reno, NV 89512. Phone (702) 784-6057, fax number (702) 784-1712. Stuart P. Hardegree is at the USDA-ARS Northwest Watershed Research Center, 800 Park Blvd. Plaza IV, Suite 105, Boise, ID 83712. Phone (208) 334-1363, fax number (208) 334-1502. ◆

MIKE PELLANT

In southern Idaho, a green strip of a forage plant, kochia, reduces the risk of a wildfire spreading across dry rangeland.

Searching for Plants That Make Their Own Insecticide

More bug-proof plants may be on the horizon for farmers and gardeners if ARS and university researchers have their way with a tropical palm tree.

Researchers at the Biocontrol of Insects Research Laboratory in Columbia, Missouri, have teamed up with scientists from the Universities of Missouri, Costa Rica, and Oklahoma in work that may someday result in genetically engineered plants that will make their own insecticides.

The object of their attention in this case is a 130-foot-tall, white-flowered leguminous tree that University of Missouri and Costa Rican researchers discovered in a dense lowland rain forest in Costa Rica.

Like many tropical trees, this one makes its own natural insecticide.

The palm tree's seeds were integrated into a diet that ARS microbiologist Art McIntosh and biologist Cindy Goodman concocted for lab-reared corn earworms. "Only about 5 percent of it was made up of seeds. But this was enough to kill 11 of the 12 insects," says Goodman.

This is only one of many steps that must be taken in the long process of perfecting this new biocontrol method. Researchers must still isolate the active compound. Then they will have to find the gene that controls its production, clone it, and insert it into important crop plants, such as corn, soybean, cotton, or tobacco.

If they are successful, insect pests such as the corn earworm—which costs U.S. corn growers over $1 billion a year in control measures and crop losses—may eventually be stymied in a new way.

For now, scientists are interested in seeing how many different insect pests may be deterred by the compound. So the ARS researchers will test the diet on other significant insect pests, such as the fall armyworm, black cutworm, tobacco budworm, and cabbage looper—insects that quickly develop resistance to chemicals now used to control them.

Scientists want to integrate new biocontrol methods into existing pest control programs. By doing so, they could reduce the use of insecticides and lessen the chance of insects developing resistance. Overall, using fewer insecticides would be better for the environment and could reduce farmers' crop production costs.

Another way to use this natural insecticide would be for researchers to insert the gene governing its production into an insect virus.

"Viruses that attack insects could be more effective if they worked faster than they do now. Some insect-attacking viruses can take as long as 2 or 3 days to kill the insects. That's too long. In that amount of time, lots of damage can be done to a crop," says Goodman.—By **Linda Cooke,** ARS.

Cindy Goodman and Art McIntosh are at the USDA-ARS Biological Control of Insects Research Laboratory, Rte. K, P.O. Box 7629, Research Park, Columbia, MO 65205. Phone (314) 875-5361, fax number (314) 875-4261. ◆

Scientists Sort Out Major Corn Virus Diseases

A corn disease caused by the maize chlorotic dwarf virus can sometimes drastically decrease yields in the Midwest and South, easily qualifying MCDV as one of the most serious viruses in corn. But the virus that's most widespread in corn worldwide is maize dwarf mosaic virus (MDMV), which can also severely reduce yields if infection occurs when plants are young.

Through the teamwork of ARS plant virologist Roy E. Gingery and other ARS and Ohio State University scientists at the Ohio Agricultural Research and Development Center (OARDC), Wooster, new methods for controlling these viruses—along with wheat streak mosaic virus (WSMV)—may soon be forthcoming.

WSMV is carried by a mite to corn from adjacent fields of infected wheat. Controlling WSMV and MDMV may also help reduce corn lethal necrosis disease, a devastating disease in parts of Kansas and Nebraska, that is caused by double infections of yet another virus, maize chlorotic mottle virus (MCMV), and either WSMV or MDMV.

ARS plant geneticist Michael D. McMullen, plant pathologist Raymond Louie, agronomist (retired) William R. Findley, and entomologist (retired) John K. Knoke have identified a gene in one inbred corn line that confers resistance to five strains of aphid-transmitted MDMV.

Until recently, some strains of MDMV could be distinguished from one another only by the way they affected certain breeding lines of corn. Now the scientists can distinguish all six MDMV strains by a serological technique called electroblot immune assay.

"The assay system may enable us to keep close tabs on MDMV and perhaps gain insights into how viruses evolve," says Gingery.

Gingery and OARDC entomologist Lowell R. Nault also discovered that two strains of MCDV which by themselves cause only mild disease symptoms, can work synergistically to cause more serious disease. "We can easily tell the two strains apart by the size of the viral proteins as well as by serological and nucleic acid hybridization tests," Gingery says.

In another study, Gingery and his colleagues found that the insect vector of MCDV, a leafhopper, could not transmit purified MCDV to corn plants unless it first fed on other plants infected with MCDV and picked up a "helper" protein produced by MCDV. "We think the protein might glue the virus to the leafhopper's mouthparts until it feeds on other plants," says Gingery.

Further research on interactions between the viruses and insects may lead to new strategies for biological control of corn virus diseases.—By **Ben Hardin,** ARS.

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